**Original Research Article**

**EFFECT OF SOWING TIME AND NUTRIENTS ON THE GROWTH AND YIELD OF BUTTERNUT SQUASH (*Cucurbita moschata*)**

**Abstract**:

Optimizing sowing time and nutrient management is critical for improving butternut squash productivity, yet their synergistic effects remain understudied in subtropical climates. A two-year field experiment (November 2022–March 2023) at Sher-e-Bangla Agricultural University, Bangladesh, evaluated three sowing dates (T1: 25 November; T2: 10 December; T3: 25 December) and four nutrient regimes (F0: Cowdung 20 t/ha; F1: N₅₀P₂₀K₄₀S₁₀Zn₁.₀ kg/ha; F2: N₇₅P₃₅K₆₀S₂₀Zn₂.₀ kg/ha; F3: N₉₀P₅₀K₈₀S₃₀Zn₃.₀ kg/ha) using a Randomized Complete Block Design (RCBD) with three replications. Early sowing (T1) significantly enhanced reproductive outcomes, yielding 14.66 female flowers/plant, 5.99 fruits/plant, and 10.33 t/ha, whereas late sowing (T3) reduced these parameters to 9.46 flowers, 3.55 fruits, and 3.78 t/ha. Among nutrient treatments, F2 maximized yield (10.00 t/ha) with 12.05 female flowers and 5.99 fruits/plant, outperforming F1 (10.16 flowers, 3.88 fruits, 5.13 t/ha). Synergistic effects were pronounced: the T1F2 combination (25 November + N₇₅P₃₅K₆₀S₂₀Zn₂.₀ kg/ha) achieved peak productivity (17.83 flowers, 7.16 fruits, 13.35 t/ha), while T3F1 (25 December + N₅₀P₂₀K₄₀S₁₀Zn₁.₀ kg/ha) resulted in minimal yield (7.17 flowers, 3.5 fruits, 2.30 t/ha). These findings demonstrate that early sowing paired with balanced NPKSZn fertilization (F2) optimizes resource allocation and yield in butternut squash, offering a scalable strategy for subtropical agroecosystems.

**Keywords**: Nutrient management, sowing time, *Cucurbita moschata*, yield optimization, reproductive phenology, subtropical agriculture.

**1. Introduction**

Butternut squash (*Cucurbita moschata*), a winter squash of the Cucurbitaceae family, is a hybrid developed in 1944 by crossing pumpkin and gooseneck squash. It is an annual vine plant with large, lobed leaves, trailing branches, and monoecious yellow-orange flowers. Its bell-shaped fruits mature in 80–140 days, yielding 3–6 fruits per plant with sweet, nutty-flavored orange flesh rich in vitamins A, C, magnesium, potassium, and calcium. These nutrients support vision, immune function, bone health, and chronic disease prevention [1,2]. Butternut’s compact size, storability [3], and adaptability to tropical/subtropical climates (21–29°C, 6–8 hours sunlight) make it commercially valuable for local and global markets [4,5].

Sowing time critically influences crop phenology, growth, and yield by modulating environmental interactions. For butternut and related cucurbits, optimal sowing aligns with temperature, light, and moisture conditions to maximize germination and vegetative-to-reproductive transitions. Studies on fennel (*Foeniculum vulgare*) and tomatillo (*Physalis philadelphica*) demonstrate that delayed sowing reduces yields due to heat stress or shortened growing periods [6,7]. For example, early sowing of cucumber (*Cucumis sativus*) ensures robust growth before high temperatures impair flowering [8]. Similarly, black cumin (*Nigella sativa*) sown in cooler periods exhibits better root development and seed yield [9,10]. For butternut, sowing during moderate temperatures (November–December) may enhance fruit set by avoiding frost and extreme heat during flowering. However, region-specific studies are limited, necessitating trials to identify ideal sowing windows under local agroclimatic conditions.

Balanced nutrient management is vital for optimizing growth, flowering, and yield. Nitrogen (N) drives vegetative growth and chlorophyll synthesis, while phosphorus (P) enhances root development, energy transfer, and flowering. Potassium (K) regulates water uptake, enzyme activation, and fruit [11]. Sulfur (S) aids protein and chlorophyll formation, and zinc (Zn) is crucial for auxin synthesis and hormone regulation. Studies on cucumber and cauliflower highlight that integrated nutrient regimes (organic + inorganic) improve biomass and yield compared to sole cowdung applications[12,13]. For instance, black cumin and kohlrabi respond positively to balanced N-P-K-S-Zn combinations, with moderate doses optimizing flower formation and fruit retention [10,14]. Excessive N, however, can delay flowering in cucurbits by prolonging vegetative phases [15]. In squash, foliar Zn and S applications enhance photosynthesis and stress tolerance [16], but optimal soil-based nutrient ratios for butternut remain understudied.

Despite butternut’s agricultural potential, limited research exists on its cultivation under specific regional conditions. Previous studies on related crops (e.g., cucumber, black cumin) emphasize the importance of sowing time and nutrient management [6,8,12] , but butternut-specific data are scarce. For instance, the interaction of sowing dates (November–December) with graded nutrient doses (N50–90, P20–50, K40–80, S10–30, Zn1.0–3.0 kg/ha) has not been systematically evaluated. Additionally, cowdung (20 t/ha), a traditional organic input, has not been compared with modern inorganic blends for butternut. Addressing these gaps is critical to formulating evidence-based recommendations for farmers. This study aims to determine the optimal sowing time, evaluate the effects of nutrient management practices, and investigate their combined influence on maximizing the growth and yield of butternut squash under regional agroclimatic conditions.

**2. MATERIAL AND METHODS**

**2.1. Description of the site**

During the rabi season, the research was conducted in the Horticulture Farm of Sher-e-Bangla Agricultural University (SAU), located in Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The experimental site is situated at a longitude of 90° 22' E and a latitude of 23° 41' N. and 8.6 meters above sea level.

**2.2. Field preparation and Treatment allocation**

The plot selected for the experiment was opened with a power tiller at the end of November 2022 and left exposed to the sun for 10 days. To achieve good tilth, the land was harrowed, ploughed, and cross-ploughed several times, followed by laddering. Pits measuring 50 × 50 × 45 cm³ were created on 10th November 2022. The experiment was laid out in a Randomized Complete Block Design (RCBD) having double factor with three replications. The experiment comprised as two factors. Factor A: Sowing time, T1 = 25 November, T2 = 10 December, T3 = 25 December, Factor B: Nutrients, F0 = Cowdung (20 ton/ha), F1 = N50P20K40S10Zn1.0 kg/ha, F2 = N75P35K60S20Zn2.0 kg/ha, F3 = N90P50K80S30Zn3.0 kg/ha. Each plot had dimensions of 4 m × 2 m, with both the row-to-row and plant-to-plant distances 2 m × 2 m. The distance between the two blocks and two plots was 1 m and 0.5 m, respectively.

#### 2.3. Fertilizers and manure application

The fertilizers and manures were applied according to the treatment. Total doses of cow dung, TSP, Gypsum, Zinc Sulphate, and a half dose of MoP were applied during pit preparation. One-third of Urea and the rest of the half dose of MoP were applied after 10 days of germination. The remaining doses of urea were applied in two equal instalments at 20 DAS and 30 DAS.

**2.4. Planting Materials and seed sowing**

The hybrid seeds of butternut were imported from Advance Seeds Company Limited, Thailand. Before sowing, seeds were exposed to partial sunlight for 30 minutes to break dormancy. They were then sown directly into prepared pits on 25th November (T1), 10th December (T2), and 25th December (T3). Two seeds were hand-sown per pit at a 2 cm depth, with light irrigation applied beforehand to ensure moist soil conditions.

**2.5. Statistical analysis**

Statistical analysis of the collected data was conducted using Statistics-10 software. Mean values for all parameters were calculated, and analysis of variance (ANOVA) was performed using the ‘F’ test. Treatment means were compared using Duncan’s Multiple Range Test (DMRT) at a 5% significance level.

**3. RESULT AND DISCUSSIONS**

**3.1. Effect of Sowing Time on Butternut Growth and Yield**

Sowing time significantly influenced butternut plant height, leaf count, branching, flowering, and yield (Table 1 and table 2). At 30 DAS, T1 (25 November) produced the tallest plants (37.83 cm) vs. T3 (25 December; 16.26 cm), a trend sustained through 140 DAS (T1: 367.37 cm; T3: 282.69 cm). Leaf count per plant was highest in T1 at 30 DAS (6.67) and 45 DAS (30.54), while T3 and T2 (10 December) showed lower values (4.93–23.13). Primary branches followed a similar pattern, with T1 leading (3.71–5.38) and T3 lagging (2.24–2.92). Earlier sowing (T1) likely provided optimal environmental conditions for vigorous vegetative growth, enhancing plant height, leaf production, and branching. Petiole length pre-flowering was longest in T1 (24.40 cm) and shortest in T3 (18.08 cm). Flowering delays occurred in T1, with first male/female flowering at 52.33 and 63.83 days, respectively, vs. 37.83 and 51.37 days in T3. T1 also produced more male (62.5) and female flowers (14.66) than T3 (30.79; 9.45). Prolonged vegetative growth in T1 likely improved resource allocation, delaying flowering but increasing flower quantity and petiole elongation. Days to first fruit harvest were longest for T1 (112.96 days) and shortest for T3 (99.42 days). Fruit yield per plant and hectare peaked in T1 (5.99 fruits; 10.33 ton/ha) and dropped in T3 (3.5 fruits; 3.78 ton/ha) (Figure 1). Extended growth phases in T1 allowed greater fruit development, offsetting delayed harvest with higher yields. Earlier sowing likely optimized temperature and photoperiod conditions, enhancing vegetative growth and resource allocation to reproductive structures, as observed in cucurbits [17]). Delayed sowing may expose plants to suboptimal environmental stress during critical growth phases, reducing photosynthetic efficiency and flower retention [18]. The correlation between extended vegetative phases and higher yields aligns with findings in warm-season crops, where early sowing maximizes growing-season benefits [19].

Fig. 1. Effect of sowing time on yield (ton/ha) at different days after sowing of butternut squash. (Here, T1: 25 November, T2: 10 December, T3: 25 December)

**3.2. Effects of Nutrients on Butternut Squash Growth and Yield**

The study evaluated three nutrient treatments: F1 (N₅₀P₂₀K₄₀S₁₀Zn₁.₀ kg/ha or 20 t/ha cowdung), F2 (N₇₅P₃₅K₆₀S₂₀Zn₂.₀ kg/ha), and F3 (N₉₀P₅₀K₈₀S₃₀Zn₃.₀ kg/ha), on butternut squash growth and yield (Table 1 and table 2). F3 promoted vigorous vegetative growth, achieving the tallest plants (30.25 cm at 30 DAS; 362.93 cm at 140 DAS), highest branch numbers (3.70 at 30 DAS; 5.00 at 45 DAS), and longest petioles (22.93 cm), likely due to higher nitrogen (N) and zinc (Zn) levels enhancing cell elongation and meristematic activity [20]. F1 underperformed in all growth parameters (shortest plants: 20.67 cm at 30 DAS; 284.74 cm at 140 DAS), reflecting insufficient nutrient availability for optimal vegetative development [21]. F2 balanced vegetative and reproductive growth. It induced the earliest male flowering (43.11 days vs. 45.05 days for F3) and female flowering (54.94 days vs. 57.72 days for F2), aligning with studies showing moderate N levels accelerate flowering by reducing excessive vegetative sinks (Xu *et al*., 2020). However, F3 produced the most male flowers (53.66 vs. 45.22 in F2), potentially due to N-induced auxin (IAA) synthesis promoting male flower formation [22]. Conversely, F2’s moderate Zn and sulfur (S) levels likely optimized female flower development (14.94 vs. 10.16 in F1), as Zn and S are critical for phytohormone regulation and ovule formation [23,24]. This translated to higher fruit numbers (5.99 vs. 3.88 in F1) and yield (10.00 t/ha vs. 5.13 t/ha in F1) (Figure 2). F3’s delayed harvest (106.94 days vs. 103.33 days for F2) and lower fruit yield suggest nutrient excess prioritized vegetative growth over reproductive allocation, a phenomenon linked to imbalanced N:K ratios [7].

Fig. 2. Effect of nutrients on yield (ton/ha) at different days after sowing of butternut squash. (Here, F0: Cowdung (20 ton/ha), F1: N50P20K40S10Zn1.0 kg/ha, F2: N75P35K60S20Zn2.0 kg/ha, F3: N90P50K80S30Zn3.0 kg/ha)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Treatment | Plant height (cm) | Number of leaves per plant | Number of primary branches | Petiole length before flowering (cm) |
| 30 DAS | 45 DAS | 140 DAS | 30 DAS | 45 DAS | 30 DAS | 45 DAS |
| Planting time |  |  |  |  |  |  |  |  |
| T1 | 37.83 a | 124.92 a | 367.37 a | 6.67 a | 30.54 a | 3.71 a | 5.38 a | 24.404a |
| T2 | 22.56 b | 121.41b | 344.77 b | 5.37 b | 23.54 b | 3.46 a | 4.08 b | 19.374 b |
| T3 | 16.26 c | 99.99 c | 282.69 c | 4.93 b | 23.13 b | 2.24 b | 2.92 c | 18.086 c |
| LSD(0.05) | 1.8144 | 2.0317 | 5.9133 | 0.5878 | 0.8248 | 0.3824 | 0.7446 | 1.2167 |
| CV% | 4.79 | 3.80 | 7.5 | 6.32 | 4.53 | 2.46 | 4.36 | 3.06 |
| Nutrients  |  |  |  |  |  |  |  |  |
| F0 | 27.54 b | 119.11 b | 344.75 b | 5.89 ab | 26.89 b | 3.36 ab | 4.28 ab | 21.083 b |
| F1 | 20.67 d | 105.02 d | 284.74 d | 4.96 c | 20.61 d | 2.56 c | 3.284 c | 18.171 c |
| F2 | 23.75 c | 111.13 c | 334.00 c | 5.44 bc | 25.56 c | 2.92 bc | 3.95 bc | 20.304 b |
| F3 | 30.25 a | 126.51a | 362.93 a | 6.33 a | 29.89 a | 3.70 a | 5.00 a | 22.927a |
| LSD(0.05) | 2.0951 | 2.3461 | 6.8281 | 0.6788 | 0.9524 | 0.4416 | 0.8598 | 1.4049 |
| CV% | 4.79 | 3.80 | 7.5 | 6.32 | 4.53 | 2.46 | 4.36 | 3.06 |

**Table 1.** **Effect of sowing time and nutrients on plant height, number of leaves per plant, number of primary branches, at different days after sowing and petiole length before flowering (cm) of butternut squash**

Here, T1: 25 November, T2: 10 December, T3: 25 December, F0: Cowdung (20 ton/ha), F1: N50P20K40S10Zn1.0 kg/ha, F2: N75P35K60S20Zn2.0 kg/ha, F3: N90P50K80S30Zn3.0 kg/ha

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Treatments | Days to 1st male flowering (DAS) | Days to 1st female flowering (DAS) | Number of male flower per plant | Number of female flower per plant | Days to 1st fruit harvest | Number of fruit per plant | Yield (kg/plant) |
| Planting time |  |  |  |  |  |  |  |
| T1 | 52.333a | 63.833a | 62.5a | 14.666a | 112.96a | 5.9988a | 4.1327a |
| T2 | 42.267 b | 54.167 b | 43.458 b | 12.958 b | 104 b | 5.1667 b | 3.2447 b |
| T3 | 37.833 c | 51.375 c | 30.792 c | 9.457 c | 99.42 c | 3.5 c | 1.5135 c |
| LSD(0.05) | 0.5234 | 0.8248 | 2.0447 | 0.8006 | 0.8098 | 0.4273 | 0.3966 |
| CV% | 4.94 | 6.19 | 3.23 | 4.20 | 5.21 | 4.58 | 5.96 |
| Nutrients  |  |  |  |  |  |  |  |
| F0 | 43.911 b | 56.167 b | 45.889 b | 12.056 b | 106.06ab | 4.8328 b | 3.016 b |
| F1 | 44.5ab | 57ab | 37.556 c | 10.166 c | 105.5 b | 3.8883 c | 2.0532 c |
| F2 | 43.111 c | 54.944 c | 45.222 b | 14.944a | 103.33 c | 5.9994a | 4.0028a |
| F3 | 45.056a | 57.722a | 53.667a | 12.276 b | 106.94a | 4.8333 b | 2.7826 b |
| LSD(0.05) | 0.6043 | 0.9524 | 2.361 | 0.9244 | 0.935 | 0.4934 | 0.458 |
| CV% | 4.94 | 6.19 | 3.23 | 4.20 | 5.21 | 4.58 | 5.96 |

**Table 2. Effect of sowing time and nutrients on days to 1st male flowering (DAS), days to 1st male flowering (DAS), number of male flower per plant, number of female flower per plant, days to 1st fruit harvest, number of fruit per plant and yield (kg/plant) of butternut squash**

Here, T1: 25 November, T2: 10 December, T3: 25 December, F0: Cowdung (20 ton/ha), F1: N50P20K40S10Zn1.0 kg/ha, F2: N75P35K60S20Zn2.0 kg/ha, F3: N90P50K80S30Zn3.0 kg/ha

**3. Combined Effects of Sowing Time and Nutrients on Butternut Squash** **Growth and Yield**

The study investigated the interaction between sowing time (T1: 25 November, T2: 10 December, T3: 25 December) and nutrient treatments (F0 : Cowdung 20 t/ha; F1: N₅₀P₂₀K₄₀S₁₀Zn₁.₀ kg/ha; F2: N₇₅P₃₅K₆₀S₂₀Zn₂.₀ kg/ha; F3: N₉₀P₅₀K₈₀S₃₀Zn₃.₀ kg/ha) on butternut squash growth and yield (table 3 and table 4). T1F3 (25 November + F3) consistently promoted vegetative vigor, achieving the tallest plants (46.83 cm at 30 DAS; 362.93 cm at 140 DAS), highest leaf numbers (7.83 at 30 and 45 DAS), and longest petioles (26.78 cm). Conversely, T3F1 (25 December + F1) underperformed, with the shortest plants (11.67 cm at 30 DAS), fewest leaves (4.05 at 30 DAS), and smallest petioles (15.26 cm). These results highlight the synergistic benefits of early sowing and high nutrient availability (F3) for vegetative growth, likely due to enhanced nutrient uptake and favorable environmental conditions during early developmental stages [25]. Branching patterns were significantly influenced by treatments. T1F3 produced the highest branch numbers (4.60 at 30 DAS; 6.67 at 45 DAS), while T3F1 yielded the lowest (1.50 at 30 DAS; 1.83 at 45 DAS). Late sowing (T3) with low nutrients (F1) restricted branching, likely due to limited assimilate partitioning under suboptimal conditions [26]

Flowering dynamics revealed trade-offs between vegetative and reproductive growth. T3F2 (25 December + F2) induced the earliest male (36.83 days) and female flowering (50.17 days), aligning with studies showing that moderate nutrient levels (F2) under shorter photoperiods accelerate floral initiation by reducing vegetative sink competition [28]. In contrast, T1F3 delayed male (53.33 days) and female flowering (65.5 days), likely due to excessive nitrogen prolonging vegetative phases [15]. Despite delayed flowering, T1F3 produced the most male (74.5) and female flowers (74.5), attributed to high nitrogen stimulating auxin (IAA)- mediated flower formation [22]. However, T1F2 (25 November + F2) optimized fruit set (7.16 fruits/plant) and yield (13.36 t/ha), demonstrating that balanced nutrients (F2) and early sowing enhance reproductive efficiency. Fruit harvest timing and yield were strongly treatment-dependent. T3F2 required the fewest days to harvest (97.83 days), whereas T1F3 delayed harvest (114.5 days), reflecting nutrient-driven growth-reproduction trade-offs. T3F1 produced the lowest yield (2.30 t/ha), emphasizing the inadequacy of low nutrient inputs in late-sown crops. Notably, cowdung (F0 ) in late sowings (T3F0 ) matched the performance of high-nutrient treatments (T3F3) in some parameters (e.g., plant height), suggesting organic amendments may partially mitigate late-sowing stress .

**Table 3. Combined effect of sowing time and nutrients on plant height, number of leaves per plant, number of primary branches, at different days after sowing, petiole length before flowering (cm), days to 1st male flowering (DAS), days to 1st male flowering (DAS), of butternut squash.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatment combinations | Plant height (cm) | Number of leaves per plant | Number of primary branches | Petiole length before flowering (cm) | Days to 1st male flowering (DAS) | Days to 1st female flowering (DAS) |
| 30 DAS | 45 DAS | 140 DAS | 30 DAS | 45 DAS | 30 DAS | 45 DAS |
| T1F0 | 39.57 b | 135.00 b | 378.50 b | 6.67 ab | 33.67 ab | 3.90 ab | 5.50 ab | 24.92 ab | 52.50 ab | 63.50 b |
| T1F1 | 30.16 d | 108.18 f | 340.33 d | 5.83 bcd | 22.00 ef | 3.00 cd | 4.35 bcde | 21.67 de | 52.17 bc | 64.50 ab |
| T1F2 | 34.75 c | 113.33 e | 355.50 c | 6.33 bc | 32.33 b | 3.33 bcd | 5.01 bc | 24.25 bc | 51.33 c | 61.83 c |
| T1F3 | 46.83 a | 143.17 a | 395.13 a | 7.83 a | 34.17 a | 4.60 a | 6.67 a | 26.78a | 53.33 a | 65.50 a |
| T2F0 | 23.67 ef | 124.43 c | 350.33 cd | 5.50 bcd | 24.00 d | 3.50 bc | 4.00 cde | 19.08 f | 41.90 ef | 53.83 ef |
| T2F1 | 20.17 fg | 118.61 d | 310.57 ef | 5.00 de | 20.67 fg | 3.17 bcd | 3.67 cde | 17.58 fg | 43.17 d | 54.50 de |
| T2F2 | 22.08 efg | 123.62 c | 346.67 cd | 5.33 cd | 22.00 ef | 3.33 bcd | 3.83 cde | 18.58 f | 41.17 f | 52.83 fg |
| T2F3 | 24.33 e | 119.00 d | 371.50 b | 5.67 bcd | 27.50 c | 3.83 b | 4.83 bcd | 22.25 cd | 42.83 de | 55.50 d |
| T3F0 | 19.39 g | 97.92 g | 305.42 f | 5.50 bcd | 23.00 de | 2.67 de | 3.33 e | 19.25 ef | 37.33 hi | 51.17 hi |
| T3F1 | 11.67 h | 88.28 h | 203.33 g | 4.05 e | 19.17 g | 1.50 f | 1.83 f | 15.26 g | 38.17 gh | 52.00 gh |
| T3F2 | 14.42 h | 96.42 g | 299.83 f | 4.67 de | 22.33 e | 2.11 ef | 3.02 ef | 18.08 f | 36.83 i | 50.17 i |
| T3F3 | 19.58 g | 117.35 de | 322.17 e | 5.50 bcd | 28.00 c | 2.67 de | 3.50 de | 19.75 ef | 39.00 g | 52.17 gh |
| LSD(0.05) | 3.6289 | 4.0635 | 11.827 | 1.1757 | 1.6497 | 0.7648 | 1.4893 | 2.4333 | 1.0467 | 1.6497 |
| CV% | 4.79 | 3.80 | 7.5 | 6.32 | 4.53 | 2.46 | 4.36 | 3.06 | 4.94 | 6.19 |

Here, T1: 25 November, T2: 10 December, T3: 25 December, F0: Cowdung (20 ton/ha), F1: N50P20K40S10Zn1.0 kg/ha, F2: N75P35K60S20Zn2.0 kg/ha, F3: N90P50K80S30Zn3.0 kg/ha

**Table 4. Combined effect of sowing time and nutrients on days to number of male flower per plant, number of female flower per plant, days to 1st fruit harvest, number of fruit per plant and yield (kg/plant) of butternut squash**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatment combinations | Number of male flower | Number of female flower | Days to 1st fruit harvest | Number of fruit per plant | Yield (kg/plant) | Yield (t/ha) |
| T1F0 | 63.15 b | 14.52 bc | 114.17 ab | 6.16 bc | 4.32 b | 10.79 b |
| T1F1 | 53.82 d | 12.83 d | 112.83 b | 5.16 de | 3.06 c | 7.67 c |
| T1F2 | 58.50 c | 17.84 a | 110.34 c | 7.16 a | 5.34 a | 13.35 a |
| T1F3 | 74.56 a | 13.50 cd | 114.50 a | 5.50 cd | 3.80 bc | 9.51 bc |
| T2F0 | 43.50 f | 12.33 de | 104.83 de | 4.85 def | 3.15 c | 7.87 c |
| T2F1 | 32.68 gh | 10.50 fg | 103.85 e | 4.05 fg | 2.16 d | 5.43 d |
| T2F2 | 47.17 ef | 15.85 b | 101.84 f | 6.50 ab | 4.53 b | 11.33 b |
| T2F3 | 50.50 de | 13.19 cd | 105.50 d | 5.33 cd | 3.13 c | 7.82 c |
| T3F0 | 31.00 h | 9.33 g | 99.17 hi | 3.57 g | 1.58 de | 3.96 de |
| T3F1 | 26.17 i | 7.17 h | 99.79 gh | 2.50 h | 0.92 e | 2.30 e |
| T3F2 | 30.00 hi | 11.17 ef | 97.83 i | 4.34 efg | 2.13 d | 5.34 d |
| T3F3 | 36.00 g | 10.16 fg | 100.32 fg | 3.67 g | 1.41 de | 3.53 de |
| LSD(0.05) | 4.0894 | 1.6012 | 1.6195 | 0.8546 | 0.7932 | 1.9831 |
| CV% | 3.23 | 4.20 | 5.21 | 4.58 | 5.96 | 5.96 |

Here, T1: 25 November, T2: 10 December, T3: 25 December, F0: Cowdung (20 ton/ha), F1: N50P20K40S10Zn1.0 kg/ha, F2: N75P35K60S20Zn2.0 kg/ha, F3: N90P50K80S30Zn3.0 kg/ha

**IV. Conclusion**

Early sowing (25 November) with balanced nutrient application (N₇₅P₃₅K₆₀S₂₀Zn₂.₀ kg/ha) optimizes butternut squash yield (13.36 ton/ha) by harmonizing vegetative vigor and reproductive efficiency, despite delayed flowering. Excessive nitrogen (N₉₀P₅₀K₈₀S₃₀Zn₃.₀ kg/ha) prioritizes vegetative growth at the expense of timely harvest, while late sowing (25 December) with low nutrients drastically reduces yield (2.30 ton/ha) due to environmental and nutritional stress. Organic amendments (cowdung) partially mitigate late-sowing limitations, but integrating optimal sowing windows with balanced fertilization remains critical for maximizing butternut productivity.

**REDERENCES:**

1. Tohill, B. C., Seymour, J., Serdula, M., Kettel-Khan, L., & Rolls, B. J. (2004). What epidemiologic studies tell us about the relationship between fruit and vegetable consumption and body weight. Nutrition Reviews, 62(10), 365–374.
2. Boffetta, P., Couto, E., Wichmann, J., Ferrari, P., Trichopoulos, D., Bueno-de-Mesquita, H. B., & Riboli, E. (2010). Fruit and vegetable intake and overall cancer risk in the European Prospective Investigation into Cancer and Nutrition (EPIC). JNCI: Journal of the National Cancer Institute, 102(8), 529–537.
3. Dari, L., & Yaro, D. (2016). Storage of butternut (*Cucurbita moschata*) squash fruit in ambient conditions in Ghana. Agriculture and Food Sciences Research, 3(1), 1–6.
4. Conti, S., Villari, G., Amalfitano, C., & Mormile, P. (2015). Effects of production system and transplanting time on yield, quality and antioxidant content of spring–summer squash (*Cucurbita pepo* L.). Scientia Horticulturae, 183, 109–115.
5. Schippers, R. R. (2000). African indigenous vegetables: An overview of the cultivated species. Natural Resources Institute.
6. Siddika, M. J., Khatun, K., Mostarin, T., Sarkar, M. I., Alam, M. M., Ferdousi, A. J., Hasan, M. J., & Afroz, S. (2022). Effect of seed sowing time and nutrients on the growth and yield of fennel (*Foeniculum vulgare*). Asian Journal of Research in Crop Science, 7(3), 1–13.
7. Shamim, A. S. A., Mostarin, T., Khatun, K., Nahar, S., Begum, T., Uzzaman, M. K., Ahmed, A., Imtiaz, A. A., Rahaman, M. A., & Samad, M. A. (2022). Growth and yield of tomatillo as influenced by planting time and macronutrients. European Journal of Nutrition & Food Safety, 14(11), 94–105.
8. Sumi, M. A., Mostarin, T., Khatun, K., Samad, M. A., Akter, S., Khanom, A., Khan, M. R., & Touhidujjaman, M. (2022). Influence of seedling age and training on yield performance of cucumber (*Cucumis sativus*). Asian Plant Research Journal, 9(1), 50–63.
9. Khan, M. R., Mostarin, T., Khatun, K., Sumon, M. M., Imtiaz, A. A., Samad, M. A., Khanom, A., & Sumi, M. A. (2022). Influence of phosphorus fertilization and seed rates on yield components and yield of black cumin (*Nigella sativa* L.). Asian Journal of Advances in Agricultural Research, 18(1), 38–50.
10. Sarkar, M. I., Khatun, K., Mostarin, T., Alam, M. M., Siddika, M. J., Saddam, M. A. H., Banik, N., & Samad, M. A. (2022). Effect of macronutrients combination with plant spacing on the growth and yield of black cumin (*Nigella sativa* L.). European Journal of Nutrition & Food Safety, 14(8), 15–27.
11. Zeng, Q., Brown, P. H., & Holtz, B. A. (2001). Soil potassium mobility and uptake by *Ziziphus jujuba* under arid field conditions. *Journal of Plant Nutrition, 24*(4-5), 575–591.
12. Malo, K., Khatun, K., Mostarin, T., Samad, M. A., Tania, M. M., Habiba, M. U., & Touhidujjaman, M. (2022). Effect of integrated nutrient management on growth and yield of cucumber (*Cucumis sativus* L.) in winter season. Journal of Global Agriculture and Ecology, 13(3), 1–12.
13. Hashi, S. N., Mostarin, T., Khatun, K., Kabir, S., Akter, S., Banu, K., Roy, S., Ahmed, A., & Samad, M. A. (2023). Effect of integrated nutrient management on growth and yield of cauliflower. European Journal of Nutrition & Food Safety, 15(1), 44–51.
14. Begum, T., Mostarin, T., Khatun, K., Shamim, A. S. A., Akter, A., Nahar, S., Mamun, F. A., Imtiaz, A. A., & Haque, M. E. (2022). Growth and yield of kohlrabi as influenced by organic and chemical sources of potassium and age of seedlings. Journal of Agriculture and Ecology Research International, 23(6), 22–31.
15. Xu, G., Fan, X. & Miller, A. J. (2020). Plant nitrogen assimilation and use efficiency. Frontiers in Plant Science, 11, 1–12. https://doi.org/10.3389/fpls.2020.00938
16. Kabir, S., Mostarin, T., Khatun, K., Hashi, S. N., Akter, S., Banu, K., Mahmud, N., Hasnine, A. A., Roy, S., & Samad, M. A. (2023). Foliar application of salicylic acid and zinc sulphate levels on growth and yield of squash under net house condition. Asian Journal of Research in Crop Science, 8(4), 71–82.
17. Kumar, R. & Reddy, K. M. (2021). Impact of climate change on cucurbitaceous vegetables in relation to increasing temperature and drought. Advances in Research on Vegetable Production Under a Changing Climate Vol. 1, 175-195.
18. Feng, X., Huai, Y., Kang, S., Yang, L., Li, Y., Feng, J. & Ning, P. (2024). Reproductive resilience of growth and nitrogen uptake underpins yield improvement in winter wheat with forced delay of sowing. Science of The Total Environment, 949, 175108.
19. Barreta, D. A., dos Santos Comassetto, D., Piran, F., Sollenberger, L. E. & Sbrissia, A. F. (2023). Species and functional diversity of cool-season pastures are influenced by warm-season grazing management. Agricultural Systems, 211, 103728
20. Marschner, H. (2012). Mineral nutrition of higher plants (3rd ed.). Academic Press.
21. Fageria, N. K. (2009). The role of plant roots in crop production. CRC Press.
22. Anjanappa, M., Rao, E. S., Kumar, N. K. S. & Krishna, R. (2012). Hormonal regulation of sex expression in cucumber (Cucumis sativus L.). Indian Journal of Horticulture, 69(3), 393–397.
23. Hussain, S., Khan, F., Hussain, H. A. & Nie, L. (2018). Physiological and biochemical mechanisms of seed priming-induced chilling tolerance in rice cultivars. Frontiers in Plant Science, 9, 1–15. https://doi.org/10.3389/fpls.2018.00355
24. Scherer, H. W. (2001). Sulphur in crop production — invited paper. Journal of Plant Nutrition and Soil Science, 164(2), 141–147. https://doi.org/10.1002/1522-2624(200104)164:2<141::AID-JPLN141>3.0.CO;2-8
25. Broadley, M. R. (2012). Fertilizers and their efficient use. In P. S. Curtis (Ed.), Encyclopedia of sustainability science and technology (pp. 1–15). Springer. https://doi.org/10.1007/978-1-4419-0851-3
26. Arshad, M., Ullah, S., Saleem, M. F. & Cheema, M. A. (2014). Growth and developmental responses of crop plants under drought stress: A review. Journal of Plant Nutrition, 37(7), 913–922. <https://doi.org/10.1080/01904167.2013.868480>
27. Edmeades, D. C. (2003). The long-term effects of manures and fertilisers on soil productivity and quality: A review. Plant and Soil, 256(1), 1–6. https://doi.org/10.1023/A:1023929515869
28. Haque, M. M., Hamid, A., and Bhuiyan, N. I. (2009). Effect of sowing date on growth and yield of summer sesame. Journal of Agricultural Science, 147(6), 629–636. https://doi.org/10.1017/S0021859609990103